Applications of Multiquantum Wells, Selective Doping, and Superlattices (Semiconductors and Semimetals, Volume 24)

Edited by Raymond Dingle

(Academic Press, 1988)

Recent progress in semiconductor nanometer growth technology has made possible the fabrication of devices with atomic-scale ultrathin layers. In these structures electrons are confined to regions comparable to their de Broglie wavelength and thus quantum mechanical effects are observable. Since the simplest model of their behavior is that of a particle in a one-dimensional box, the terms "quantum wells," or "superlattices" for the periodic versions, are used to describe these structures. The first proposal of the concept of the semiconductor superlattice was by L. Esaki in 1970. The field is still growing rapidly, influencing both fundamental physics and device technology. In particular, the demonstration of improved performance by the modulation-doped high electron mobility transistor (HEMT) and by the quantum-well laser stimulated much investigation of various issues needed to understand the behavior of these devices. The successful evolution of this field was also supported by concurrent and dramatic improvements in the growth technologies, especially molecular beam epitaxy and metal-organic vapor phase epitaxy.

Due to the field's continuing rapid growth, it is impossible to summarize all the important developments in one volume. R. Dingle, one of the original inventors of the high electron mobility transistor, has instead chosen to focus on some of the most significant topics of clear and enduring importance. The book's 13 authors are among the leading pioneers in the field. The chapters they have written are oriented to providing an introduction to the basic concepts of each topic. Because of this, the volume is still timely and useful, even though the material is a few years old.

The book is divided into four parts. The first, a single chapter by C. Weisbuch (Thomson-CSF), describes and summarizes the basic phenomena occurring in the various material systems, including the optical and electronic properties of the various structures. It provides an excellent foundation for the subsequent chapters. The second part, chapters two through four, focuses on electronic devices and circuits based on the quantum well, the superlattice, and the single selectively doped heterostructure interface. The areas covered include device physics, microwave applications, and the HEMT-integrated circuit. The authors are H. Morkoc (Illinois) et al., N.T. Linh (Picogiga), and Abe (Fujitsu) et al., respectively.

The next three chapters focus on the generation and detection of light using single (SQW) or multiple quantum well (MQW) structures. In these chapters, written by members of AT&T Bell Laboratories, D.A.B. Miller discusses the nonlinear optical properties of MQW structures for optical processing, F. Capasso explores a range of devices based on multilayer structures with both sharp and graded interfaces, and W.T. Tsang continues the exploration of the bandgap engineering concept as applied to MQW lasers. The fourth section is also the final chapter in which the concept of the strained layer superlattice structure is discussed by G.C. Osbourn et al.

This book covers much of the fundamental physics of quantum wells and superlattices and their application to devices. It provides an excellent introduction for scientists entering the field, especially the first chapter by Weisbuch. It also provides in-depth analyses of the HEMT, the quantum well laser, and other more exotic structures, which can be read profitably by those already working in these fields and desiring a more thorough understanding.

Reviewer: Y. Arakawa is an associate professor, Research Center for Advanced Science and Technology, University of Tokyo. His current research includes both the fabrication technology and physics of optical quantum microstructure devices. He has also been investigating ultrafast optoelectronics.

Handbook of Thin-Film Deposition Processes and Techniques

Edited by Klaus K. Schuegraf

(Noyes, 1988)

Thin film deposition is critical to advances in high technology. Advances in thin film processing and techniques are largely responsible for the success of electronics, optical and magnetic data storage, hard coating, and communications industries. The need for reliable information in a single reference is useful to scientists, engineers, and managers as well as students.

The *Handbook of Thin-Film Deposition Processes and Techniques* fulfills some of these needs. It thoroughly covers the topics of thin film processing and techniques. For example, the table of contents is thorough and impressive. The topics are largely handled in a tutorial way, although the overview as well as the chapters on silicon epitaxy, low-pressure CVD, plasma-assisted CVD, ECR, and in particular, molecular beam epitaxy emphasize the spirit of the title and the table of contents of the book.

A few of the chapters, however, do not meet the level of a handbook. The chapters on sputtering and ion beam deposition could have had more extensive treatment of the subject and a more extensive listing of references. As a general guide to principles, methods, equipment, and applications, the book falls short of its goals in some chapters. As a handy reference or an introductory text, it has value.

Reviewer: Jerry Cuomo, manager, Materials Laboratory of Central Scientific Services, IBM T.J. Watson Research Center, manages and conducts research in materials, processes and their interrelationship.

New Elastomer Synthesis for High Performance Applications

J.E. McGrath, G.L. Wilkes, T.C. Ward, A.D. Broske, B. Lee, I. Yilgor, D.J. Bradley, J.M. Hoover, and T.E. Long

(Noyes, 1988)

New Elastomer Synthesis for High Performance Applications is divided into five sections. The first section (6 pages) describes the design and construction of a laboratory-scale reactor for anionic and other controlled atmosphere polymerizations, and also hydrogenation. The second section (22 pages) describes investigations of hydrogenation reactions for polydiene elastomers and for branched block elastomers based on *t*-butylstyrene. The third section (27 pages) deals with the preparation and use of a hydrocarbon-soluble dilithium initiator based on 1,3-*bis* (1-phenylethenyl)benzene. The fourth section (17 pages) describes the preparation and properties of ion-containing polymers using both anionic and emulsion polymerization techniques. The fifth section (35 pages) describes preparation, properties, and morphology of poly(urea-urethane) elastomers.

The book's title may be somewhat misleading because "high performance" in this text generally refers to possible higher temperature applications and somewhat (e.g., hydrogenation of polydiene elastomers) to better oxidative and aging stability. The first section dealing with the "invention" of a laboratory-scale, low-pressure reactor is not informative enough for someone to construct such a system since only a schematic diagram is provided without references for equipment and plumbing other than for the source of the commercial reactor.

The second section on hydrogenation of dienes applies the idea of preparing more stable block copolymers by hydrogenating the polydiene blocks. This concept is commercially practiced in the Kraton G materials manufactured by Shell. Here it is applied to block copolymers based on *t*-butylstyrene whose blocks undergo useful phase separation only on hydrogenation of the polydiene blocks using catalysts described previously in the literature.

The third section deals with a specific dilithium initiator which has been developed and patented by L.H. Tung and coworkers at Dow Chemical Company. This section primarily considers the kinetics of adding butyllithium to 1,3-*bis*(1-phenylethenyl)benzene. Readers should consult a recent paper by Tung and co-workers (in *Advances in Elastomers and Rubber Elasticity*, edited by J. Lal and J.E. Mark, Plenum, 1986, p. 129) for details on block polymer syntheses using this initiator. This chapter appears to be a verbatim rendition of a paper published in *Recent Advances in Anionic Polymerization*, edited by J. Hogen-Esch and J. Smid, (Elsevier, 1987, p. 363).

The fourth section describes synthetic methods for preparing well-defined ionomeric structures based on anionic polymerization to form polystyrene-block-poly(isobutyl methacrylate) diblock copolymers which can be hydrolyzed using potassium superoxide to the corresponding ionomeric block polymers. In addition, emulsion copolymerization of sodium-p-styrene sulfonate with *n*-butylacrylate is described and evidence for a blocky structure presented. Enhanced physical properties are reported for the ionomers versus the corresponding homopolymers, blends or the un-ionized block copolymers.

The fifth section on poly(urea-urethane) elastomers is the largest chapter in the book. These polymers were prepared from poly(tetramethylene oxide) glycols of varying molecular weight which were endcapped with excess diisocyanates by reacting them with tertiary alcohols which convert excess isocyanate groups to amine groups. The resulting segmented copolymers with varying hard-segment compositions, soft-segment molecular weights, and diisocyanates were characterized by differential scanning calorimetry, thermal mechanical analysis, mechanical properties, small angle x-ray and wide-angle x-ray analysis and compared with analogous segmented polyurethanes. The experimental evidence suggests enhanced mechanical and thermal properties for the poly(urea-urethane)elatomers relative to analogous polyurethanes.

In conclusion, this text is a potpourri of unevenly presented topics with a loose thread of continuity based on the authors' concepts of high performance. Since it contains a rather specialized collection of papers, it is not the type of text most readers would include in a personal library.

Reviewer: Roderic P. Quirk is professor of polymer science, University of Akron, with an active research program in synthetic organic polymer chemistry emphasizing anionic polymerization, chain-end functionalization, and block and branched copolymer synthesis.

Diffusion Phenomena in Thin Films and Microelectronic Materials

Edited by Devendra Gupta and Paul S. Ho

(Noyes, 1988)

This book is a timely compilation of current knowledge in the intellectually challenging and technologically important field of diffusion processes and phenomena in thin films and some classes of microelectronic materials. The individual chapter authors are well respected researchers in the relevant subject areas, and both an authoritative introduction to the theoretical background and a useful compilation of available experimental data are presented for each topic.

The first chapter introduces diffusional phenomena in general, with considerable emphasis on grain boundary diffusion, and covers the thorny problem of the relationship between grain boundary structure, composition and diffusion kinetics. The use of anelastic relaxation measurements to study diffusion and grain boundary sliding in thin films is then discussed. This technique has not been widely applied to microelectronic materials, yet it promises to give detailed information on the atomistic processes during diffusion and creep of microelectronic films.

The third chapter considers diffusion in compositionally modulated films, a topic of considerable importance for the long-term stability of both metallic and semiconductor artificial superlattices. The dominant role of grain boundaries in controlling the rate of growth of crystalline oxides is discussed in Chapter 4, but a section on the mechanisms of growth of SiO_2 is included as well.

The fifth chapter is a comprehensive discussion of our understanding of the long-neglected phenomenon of diffusion-induced grain boundary migration. This is a particularly valuable contribution, clearly showing that mass transport processes in all kinds of thin films may often be dominated by DIGM. The last of the more general topics considered in this book is the effect of ambiants on thin film interactions. Here it is argued that modifications to the surface potentials of a layered metallic structure can strongly influence chemical reactions and diffusion processes in the buried layers.

The final four chapters are on topics more directly related to microelectronic materials, but draw strongly on the fundamental phenomena described in the earlier chapters. Electromigration is discussed both in thin metallic conductors and in relatively more massive solder connections. Particularly in the thin film materials it is shown that the detailed microstructure of the conductors has a most important effect on the overall stability of integrated metallization. The theory and practicalities of choosing and preparing reliable diffusion barriers is discussed in Chapter 8, and the more specialized field of metallization for low temperature Josephson devices in Chapter 9. In each of these four topics, it is shown that the concentrations of solute or impurity elements can be important in controlling phenomena like grain boundary sliding, diffusion, and DIGM.

This volume is thus a significant contribution to the complex field of transport and deformation phenomena in thin films, especially, but not exclusively, those of importance in microelectronic device fabrication. It should prove of most value to researchers in thin films, but is written at a level so that many graduate students will benefit from the combination of theory and experimental data.

Reviewer: Chris Grovenor is an information technology lecturer at Oxford University. His research interests include the development of analytical techniques to study the microstructure of thin films, and the application of these techniques to develop an understanding of growth and interdiffusion phenomena. □